U.S. Department of Agriculture Agricultural Research Service June 1989

Agricultural Research

Mysteries of Infant Nutrition

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Filling the Rice Bowl

America, once the world's leading exporter of rice, has recently fallen into second place. Countries such as Thailand—the current leader—can beat us on price and are catching up with us on quality. The paddies of our major rice-growing states—Arkansas, California, Louisiana, Texas, Mississippi, and Missouri—still produce the finest long-grain rice any currency can buy. But our competitors are learning how to produce rice with nearly the same outstanding cooking quality that was once uniquely ours. As the quality gap narrows, our sales suffer.

Here at home, rice producers face demands of a market that is growing and diversifying. U.S. consumers are buying more rice now than ever before. People from other countries who settle here are bringing with them strong preferences for the familiar rices of their homelands, such as the lightly scented varieties so popular in Asia and the Middle East.

Can U.S. rice producers meet the new challenges at home and abroad, that is, regain export leadership yet satisfy the shifting desires of the expanding domestic market, as well?

I think so, but not without the help of research. The key to outdoing international competitors is to boost yields, thereby reducing production costs, and to further improve milling and cooking qualities, so our rice remains superior to that of our competition.

Right now, U.S. acreage devoted to rice production is only about 2.5 million acres, small in comparison to the 350 million acres used worldwide for growing rice. But more than half of our production is sold overseas. Iraq and Saudi Arabia are our best customers; Senegal, Liberia, South Africa, Canada, and Belgium are also major purchasers. Typically, these customers will pay a premium for American rice. However, when the asking price exceeds that of other producers by about 25 percent, U.S. growers lose sales.

The surest way growers can keep their production costs in check is to boost yields without increasing costly inputs, such as fertilizer. Research has helped growers do just that.

Scientists have developed sturdy, semi-dwarf rice varieties that have increased yields about 20 percent. But more needs to be done. At sites like the ARS laboratories in Stuttgart, Arkansas, and Beaumont, Texas, agronomists work with geneticists to find other prized traits that might be introduced into these or other new varieties. The Beaumont researchers have developed a unique long-grain rice—the "Newrex" type—that should help keep the United States competitive in international markets.

For these scientists and others around the world, ARS maintains more than 12,000 specimens of rice in the National Small Grains Germplasm Research Facility at Aberdeen, Idaho. Breeders look to this worldwide collection for new sources of useful genes.

Insects and diseases can erode yields, cause costs to soar, and rob growers of profits. ARS researchers and their university and industry colleagues in the major rice states are fighting back, trying to minimize losses caused by insects such as the rice water weevil and stinkbug, and by diseases like blast, sheath blight, and stem rot.

What is research doing to help growers stay competitive in the changing domestic market? ARS scientists are working with industry and university colleagues to develop exotic rices like the scented and glutinous (extra-sticky) varieties. Industry researchers in California seek additional "premium" medium-grain rices that would grow well in this country. Medium-grain (and short-grain) rices cook moist and chewy, a quality many people of Asian ancestry prefer to the dry, fluffy texture of long-grain rice, the predominant type grown and sold in the United States today.

Chemists, engineers, and food technologists at the Southern Regional Research Center, New Orleans, and Western Regional Research Center at Albany, California, are developing new products and new cooking processes, all aimed at increasing rice's popularity among American consumers.

A process Albany scientists developed for preventing rancidity in rice bran has led to new interest in bran as a tasty, nutritious, high-fiber ingredient in cereals, breads, and similar products. Consumers at home and abroad would benefit from Beltsville, Maryland, research aimed at improving the proteins rice provides (see story, this issue). In the coming years, biotechnology—perhaps more than any other aspect of rice research—may dictate how well science assists growers in satisfying American and international customers.

Biotechnology may hold the answer to practical, economical production of hybrid rice with yields that could outpace those of even the increasingly popular semi-dwarfs. What's needed is a hybrid that essentially clones itself, effortlessly producing seeds that are exact replicas of the parent. This trait occurs in some grasses and is controlled by genes. If we can use tools of modern biotechnology to transfer those genes into rice, we'd have the hybrids we dream of.

If I'd proposed such a scheme when I was just starting out in rice research 18 years ago, people would have thought I'd stayed in the hot sun too long. Today, even a skeptical scientist might admit that we may be able to produce hybrid rice, through genetic engineering, within this century.

J. Neil Rutger
ARS, Stoneville, Mississippi.

Agricultural Research

Cover: Human milk fat provides a substantial amount of energy to infants. Exploring a nursing mother's ability to produce fat is aided by the use of stable isotope tracers in studies carried out at ARS' Children's Nutrition Research Center in Houston, Texas. Photo by Jack Dykinga. (K-3096-2)

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DEPARTMENTS

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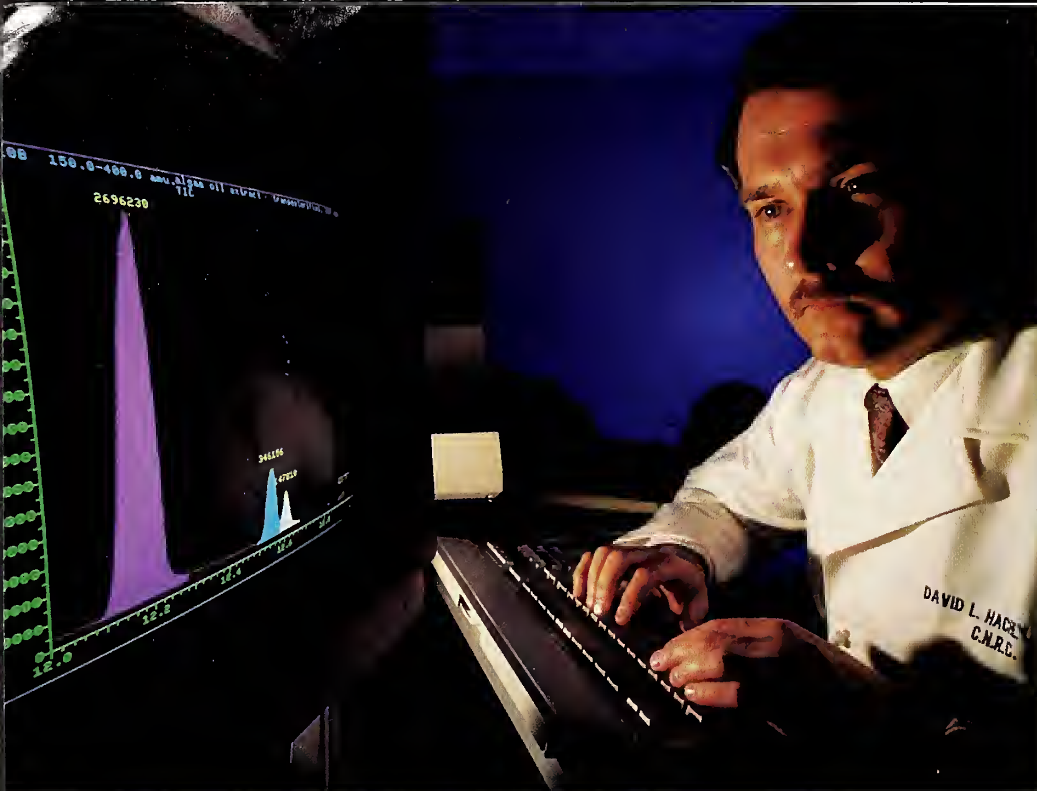


JACK DYKINGA

Chemist David Hachey studies mass spectrometer data display of stable isotope enrichment of human milk fat. (K-3099-7)

Silent Tracers Leave Their Mark

Just as biologists tag the legs of wild birds to follow their movements or learn where they stop off to feed or mate, chemists can tag nutrients—fats, proteins, carbohydrates, minerals, even water—and watch what the body does with them.

Thanks to a quirk of nature, each of the biologically important elements—carbon, hydrogen, oxygen, and nitrogen—exists in two or more forms that differ only in their weight. And there is a constant proportion in nature between the common form and the heavier form, known in chemical parlance as the stable isotope. For example, slightly more than 1 percent of all carbon in nature—1.11 percent to be exact—is carbon-13 (^{13}C). It has one more neutron in its core than common carbon-12 but one less than carbon-14, which is radioactive.

"Stable isotopes are often called silent tracers because they emit no measurable radiation," says Peter D. Klein, who heads what is becoming a world-renowned laboratory for measuring these tags. The Stable Isotopes Laboratory is located at the Agricultural Research Service Children's Nutrition Research Center at Baylor University in Houston.

Not only are they completely safe to use, says Klein, their use does not generally involve drawing blood or other invasive techniques. They can be given by mouth and later measured in breath, saliva, breast milk, urine, or stool samples and are therefore ideal for studies of infants, children, and pregnant and nursing mothers.

The list of questions that stable isotopes can help answer is nearly endless. So scientists in the Stable Isotopes Laboratory at the Houston center, which is staffed by the Baylor College of Medicine, are playing a lot of tag these days in a host of research projects that will lead to a better understanding of the nutritional needs of infants and children.

A Cereal Drama

In one study, pediatrician Robert Shulman successfully used the fact that foods naturally differ in their ^{13}C levels to show that infants can digest cereals 3 to 5 months earlier than had been thought. Newborns don't make enough amylase—the principal starch-digesting enzyme in adults—to allow much digestion of cereals. Based on this fact, the American Academy of Pediatrics recommends not feeding cereal before 4 to 6 months of age.

But very young infants seem able to handle cereal and other complex

JACK DYKINGA

Chemist William Wong estimates infant energy expenditure by analyzing their urine using stable isotope techniques. (K-3106-2)

carbohydrates better than should be expected, he says.

To learn why and how, Shulman fed 1-month-olds a formula made from soybeans and beet sugar—which are naturally low in ^{13}C—to reduce levels of ^{13}C in the carbon dioxide they exhaled. That way he could measure an increase in breath ^{13}C if the infants were digesting, absorbing and, of course, metabolizing corn cereal—which is naturally high in ^{13}C. He found that the small babies absorbed about three quarters of the corn cereal they consumed—more than he had anticipated. Some of it was being digested and absorbed through the small intestine and some assimilated through the colon.

As Shulman explains it, bacteria inhabiting the colon convert some of the undigested cereal into fatty acids, which the body can absorb and use for energy. This conversion also produces hydrogen gas, which is absorbed and exhaled through the breath. So when the infants are metabolizing fatty acids from the colon, they exhale more hydrogen than they do when metabolizing cereal from the small intestine. Since ^{13}C began increasing in their breath well before the hydrogen concentration increased, they must have begun absorbing some of the cereal through the small intestine. In a second study, Shulman determined which enzymes were taking the place of amylase.

Doctor Knows Best, After All

What about rice cereal? That's the one doctors prescribe most as baby's first solid food. But rice is one of those grains that is naturally low in ^{13}C, making its absorption difficult to detect. No problem.

Plant physiologist Tom Boutton, now at Texas A&M University, worked with scientists at ARS' rice-breeding facility in Beaumont, Texas, to provide ^{13}C-enriched grain. [See box.] And the Gerber Company processed it into rice cereal.

Shulman now had the tools to answer several more questions about feeding cereal to very young infants. Does giving them cereal raise nutrient intake, or does it fill them up so they consume less milk? Will undigested cereal drag other nutrients out of the small intestine and impair their absorption? And how much of the cereal actually winds up in the stool unused?

The eight infants in this study got one tablespoon of stable-isotope-labeled rice cereal per ounce of formula in their bottles. "That's substantially more [cereal] than a mother would normally feed her baby," he

Growing Carbon-13 Rice

You can't exactly stop by the local grocery store for a box of rice labeled with carbon-13—a stable nonradioactive variant of the common element—when you need some.

So when the scientists at ARS' Children's Nutrition Research Center needed ^{13}C-labeled rice for an experiment tracing how soon infants can digest rice cereal, they asked the ARS Rice Research Laboratory in Beaumont, Texas, to grow it.

Each summer for the last 3 years, just as the grains began to fill on the heads of the rice stalks, ARS plant breeder Charles Bollich and his crew wheeled a 2- by 4- by 5-foot Plexiglas chamber out to the fields and blew carbon dioxide gas at the rice for a day.

The carbon dioxide gas is enriched with a high level of ^{13}C.

In addition to helping the scientists at the Children's Nutrition Research Center with their work, the ^{13}C is giving Bollich and other researchers new information about how crops direct carbohydrates into the different parts of the plant.

"Essentially, the rice breathes in the carbon dioxide and directs the carbon into the photosynthesis cycle," Bollich says. "Then we can trace the flow of the ^{13}C as the plant places the carbon in the grain as carbohydrates or into the leaves or roots."

Within hours of exposure to the carbon dioxide, the ^{13}C can be found in the rice grains, reports Bollich.

"What we want to know is the control factor," he says. "What determines the direction of the carbon flow within the plant? What controls whether a particular molecule becomes part of a leaf, a root, a grain?"

If the control factor can be identified, someday it may be possible to direct plants to put fewer resources into the body of the plant and more into the harvestable parts.

As for the Nutrition Center study, once the labeled rice is harvested, the Gerber Company turns it into rice cereal for the babies to eat.—By **Kim Kaplan,** ARS.

Charles Bollich is at the USDA-ARS Rice Research Laboratory, Rte. 7, P.O. Box 999, Beaumont, TX 77713 (409) 752-5221.

says, but it's the amount pediatricians recommend for small infants who regularly spit up liquid formula.

Differences in the ^{13}C levels in their breath before and after the feeding showed they had absorbed or assimilated most of the rice cereal—88 percent on average. But their net retention of protein and calories was no higher than when they got formula alone. "Despite the fact that they were eating more, they didn't absorb more," says Shulman. "The extra nutrients were just passing through."

So although 1-month-old infants can handle cereals, says Shulman, "there doesn't seem to be any nutritional benefit, in terms of protein and calories, to feeding cereal earlier than recommended."

Mothers commonly begin cereal earlier than 4 months to help their infants sleep through the night, he says, and there is some scientific evidence that it does. But there is also some evidence that undigested cereal may drag minerals out of the small intestine.

"Our own studies support the recommendation of the American Academy of Pediatrics," he concludes.

A Breath Sample, Please . . .

^{13}C breath tests also make excellent, noninvasive diagnostic tools. With funds from the National Institutes of Health, Klein is developing a test to detect an infection that can lead to ulcers and possibly even stomach cancer. He is also fine-tuning tests to measure fat malabsorption and determine its cause and to measure liver function.

Quite accidentally, while checking the sensitivity of the test for liver function—the aminopyrine breath test—Klein found that several of his student volunteers had very low scores. And they were all females! After some detective work, he realized that the women with the abnormally low liver function were all using oral contraceptives. "The steroids (in oral contraceptives) have a very pronounced effect on the liver," he says.


JACK DYKINGA

Chemist David Hachey observes as lab technician Linda Ellena prepares a sample of human milk fat for analysis in a gas chromatograph mass spectrometer. (K-3102-4)

He then tested 16 women taking 1 of 2 preparations. "After 3 weeks on the pill, 11 of the 16 women had scores in the range that would indicate liver cirrhosis—the alcoholic's disease," he says. However, liver function improved—and in most cases almost doubled—within 7 days of stopping the steroids.

Klein is now testing preparations with lower and higher levels of estrogen to see if the scores vary accordingly. One thing Klein now knows for sure, "The aminopyrine breath test is a very sensitive test of liver function."

Such breath tests are easy on the subjects being studied, he says. But, unlike tests using radioactive isotopes, stable isotope tests require expensive instruments and plenty of expertise. And so they are not in general use for diagnosing health problems.

The Bright Side of Body Fat

With the center's wealth of instruments at his fingertips, David L. Hachey now understands why women store more fat during pregnancy. "It's to have a pool to draw from for lactation."

Hachey is studying the fat composition of human breast milk because half the calories in breast milk are from fat, making it the infant's major source of energy for the first few months. In one study, he enriched the three types of fatty acids—saturated and mono and polyunsaturated—with heavy hydrogen (deuterium) and fed them to three nursing women.

By analyzing their milk for changes in the ratio of deuterium to hydrogen, he determined that the breast used all three fatty acid types about equally in producing milk. But only about 30 percent of the fat in the milk came directly from the diet. Most of it—about 60 percent—came from stored fat, he says. "Since a nursing mother puts out about 20 grams of fat in her milk each day, each pound of body fat provides enough fat for 3 to 4 weeks of lactation."

In a second study, using fatty acids labeled with ^{13}C instead of deuterium, Hachey looked at the effect of high-fat and low-fat diets on breast milk fat and cholesterol. "Fat is thought to be the most variable nutrient in breast milk," he explains, noting that he has seen fat concentration as low as 1.5 percent and as high as 6 percent. It is normally 3.5 percent—about the same as cow's milk.

Indeed, the low-fat diet caused dramatic changes in how the women's bodies handled their limited fat supply, but it didn't reduce the total fat and cholesterol content of their milk. The percentage of fat and cholesterol dropped a little, he says,

but the total volume of milk increased so there was no net change in their daily fat output. Contrary to current thinking, "the mammary gland works to protect total fat secretion despite a restricted fat intake," says Hachey. The women simply secreted a bit more water, lactose, and protein to produce milk."

Heavy Water, Weighty Results

Researchers routinely use water containing deuterium (heavy hydrogen) to estimate a person's body composition. The heavy water—D_2O—presumably mixes evenly throughout a person's body and becomes diluted according to the total amount of water in that body. With a few calculations, one can estimate a person's total body water, which translates into their lean body mass. The remainder of their weight represents body fat.

Water containing heavy oxygen (^{18}O) instead gives a more accurate estimate, says Klein, but is rarely used because ^{18}O is far more expensive than deuterium and its detection requires a mass spectrometer. So when he collaborated with researchers in Peru to learn why children there "appear to be very stocky" he used ^{18}O.

The children under study had a high weight-to-height ratio, he says, which could be due either to stunting or to obesity. He found the excess weight was not due to fat but to water. "Probably because they are protein deficient," he explains, "their lean body mass is, you might say, more soggy than a normal child's. Consequently, they weigh more."

Chemist William Wong of the stable isotopes group has been running both deuterium and ^{18}O through their paces in studies with nursing mothers, infants, even premature infants to nail down the correction factors that must be used when calculating body composition from breast milk, urine, breath, and saliva samples.

"In all calculations, we have to apply corrections for urine and saliva samples to make them equivalent to blood samples," he notes. His efforts have led to the first round-the-clock measurements of energy expended by healthy infants.

Studies at the Houston center and elsewhere show that breast-fed infants take in fewer calories than formula-fed infants. Breast-fed infants also grow more slowly after the fourth month, but not slowly enough to account for their 20-percent lower calorie intake.

Do they need fewer calories because they burn fewer calories?

According to Nancy Butte, a nutritionist at the center, breast-fed infants consume significantly fewer calories than the current Recommended Dietary Allowance, but the RDA is based predominantly on calorie intakes of formula-fed infants. So, are breast-fed infants getting less energy than they need for optimal growth and development as the current RDA's suggest? Or, are we overfeeding with formula?

To help answer these questions, Butte turned to Wong and to doubly-labeled water—with both deuterium and ^{18}O. They estimated daily energy expenditure of 20 breast-

JACK DYKINGA

In studies to determine just how much energy is being used for growth, chemist William Wong and nutritionist Nancy Butte take an infant's weight and length measurements. (K-3103-7)

fed infants and 20 formula-fed infants at both 1 and 4 months of age.

Sure enough, the breast-fed infants burned 5 percent fewer calories at 1 month and 12 percent fewer at 4 months than the formula-fed group. The difference seemed to be due to lower sleeping, or basal, metabolic rates, not to lower activity level, says Butte. It appears that breast-fed infants need fewer calories to "idle," just as some automobiles use less gas when standing in neutral.

During the study, Wong also estimated body composition to see if formula-fed infants channeled some of their extra calories into extra fat. Since fat has more than twice the calories of protein, more calories are stored in fat tissue than in lean. But the "formula-fed infants turned out to be no fatter than their breast-fed counterparts," says Wong.

Formula-fed babies burn some of their extra calories and funnel the rest into growth, says Butte. But based on the study findings, she holds that "mother's milk provides adequate energy for the first 4 months. After that, infants may need to receive supplements."

Tracing Cholesterol Production

Klein is most excited about his team's ability to measure how fast the body makes its own cholesterol so they can see how diet or drugs affect the apparent rate of synthesis.

Says Hachey, who specializes in fat and cholesterol studies, the current thinking is that a higher turnover of cholesterol is a good sign. Apparently, high blood cholesterol is most often due to the body's inability to remove it efficiently. The faster the body eliminates cholesterol, the faster the liver has to make it to maintain a constant level, he explains.

A method for measuring this rate has wide application for all ages. And being able to assess how children and adolescents respond to the types and amounts of dietary fats would help settle the controversy over when to start reducing the fat in their diets, he notes.

According to Klein, the idea for measuring cholesterol synthesis is not new. More than 50 years ago, two scientists at Columbia University discovered that the body draws on its own water pool to supply about half the hydrogen atoms in its homemade cholesterol. "Therefore, you can tag the cholesterol by feeding a person deuterium," he says. Trouble was, researchers have had to feed deuterium for months before they could get a detectable increase in the homemade cholesterol. Not any more. Bill Wong developed a far more sensitive method that detects minute increases in deuterium.

"Formula-fed infants turned out to be no fatter than their breast-fed counterparts."

William Wong, Chemist, Houston, Texas

The number of steps involved in his method and the precision required were almost beyond belief, but "we can now measure cholesterol synthesis over a short period, 1 to 3 days," says Klein.

Hachey and Wong worked with William Insull, a physician with Baylor College of Medicine, to devise the new approach for measuring cholesterol synthesis. It just so happens that the liver is constantly swapping its free cholesterol with cholesterol in red blood cells, compared with a much slower exchange of cholesterol between the liver and blood plasma, explains Klein. "So if you get a good sample of red-blood-cell cholesterol you know exactly what's going on in the liver." An increase or decrease in red-blood-cell cholesterol—measured by changes in its deuterium level—mirrors an increase or decrease in cholesterol synthesis in the liver.

Once the researchers establish a person's "baseline" rate of synthesis, they can alter the diet or give drugs and monitor any changes in subsequent blood samples.

The team has come a long way from the old techniques, but they're not finished yet. They want to make accurate measurements without making too many demands on the subject, especially when he or she may be an infant. With the help of Ji Jiang, a visiting scientist from China, "we're cutting down on the number of samples and trying to improve cholesterol recovery to reduce the amount of blood we have to draw," says Wong. They've reduced the amount per sample from 20 to 10 milliliters and are close to needing only 5 ml—about a teaspoonful.

Says Klein, "We're down in the range where we can do this test on fairly young infants—maybe 4 months old."

And a big issue they plan to study is the effect of breast feeding vs. formula feeding on cholesterol synthesis. Breast milk contains cholesterol, and formula doesn't, Klein says. "We're predicting that the breast-fed babies are going to have higher serum cholesterol, and they're going to synthesize much less cholesterol than formula-fed babies because dietary cholesterol shuts off cholesterol synthesis."—By **Judy McBride,** ARS.

All of the scientists mentioned in this article, except Thomas Boutton, are at the ARS Children's Nutrition Research Center, 1100 Bates St., Houston, TX 77030. (713) 798-7000. Boutton is at Texas A&M University, College Station, TX 77843. ◆

Nutritionally Enhanced Rice Genetically True

Test-tube rice plants with better protein quality—and more protein too—have raised hopes that more nutritious varieties of rice can be bred. And now, scientists say, these plants are a step closer to the nation's rice paddies. The plants have proven to be true genetic mutants, and therefore suitable for breeding new commercial varieties.

The high-protein rice plants are mutants of Calrose 76, a commercial variety. The mutants contain 10 to 20 percent more of the essential amino acid lysine than Calrose 76 rice. The higher lysine leads to more protein in the grain.

Plant physiologist Gideon W. Schaeffer, support biologist Francis T. Sharpe, Jr., and technician John Dudley found that the high lysine trait is apparently controlled by a single recessive gene. After four generations of crossbreeding, the gene for producing high lysine levels is still passed to progeny plants.

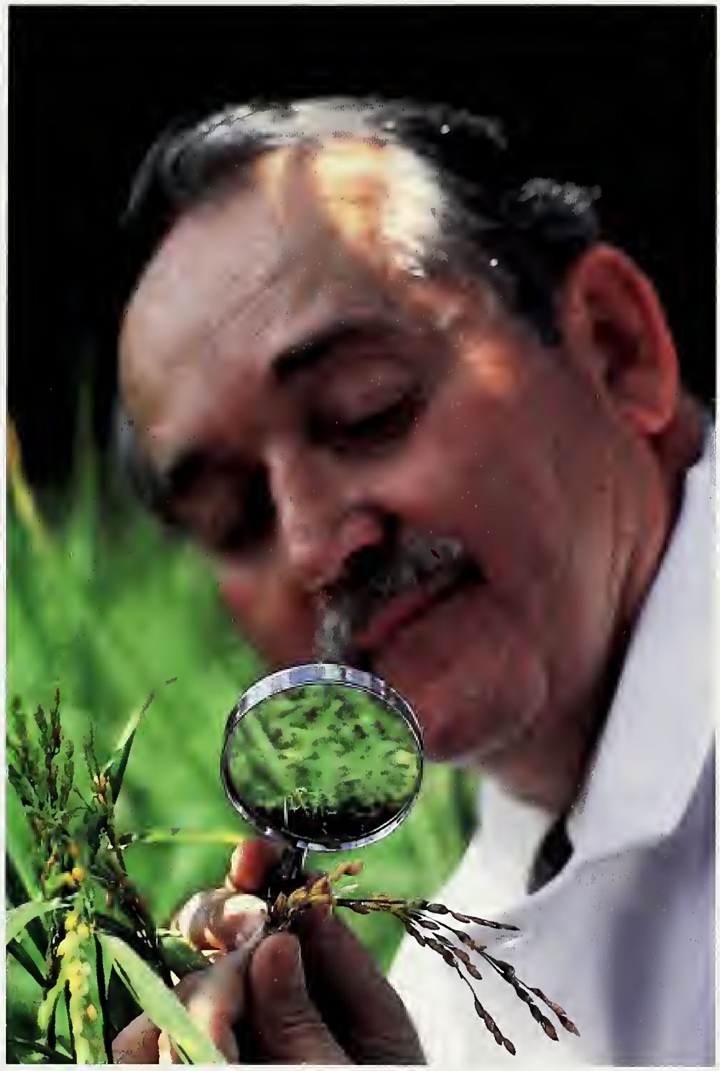
According to nutritionists, the nourishment value of cereal grains would get a firm boost if they could be bred to contain more lysine.

The scientists first produced rice with high lysine and high protein from tissue cultures in the laboratory in 1981. Unfortunately, those first plants were not well adapted to growing on the farm.

Now scientists have repeated the tissue culture experiments for the third time, with a commercial rice variety. This time, some of the recent crossbreeds have succeeded in producing seed of near-normal weights and good fertility, which is important to further breeding.

Schaeffer says that the work is probably the first demonstration of a laboratory selection technique to make "a substantial improvement in the protein nutrition of a cereal variety." The laboratory technique—more commonly used to force mutations in cultures of bacteria and other simple microorganisms—is called inhibitor selection.

Schaeffer explains that as proteins are built from various amino acids in cells of rice plants, a chain of chemical reactions casts amino acids from simpler compounds. When the cell has made enough lysine, for example, for its seed protein, it feeds a signal back through the chain, shutting down, or inhibiting, further lysine production.



KEITH WELLER

Plant physiologist Gideon Schaeffer pioneered a tissue culture technique that led to rice with more protein and a much needed improvement in lysine, an essential amino acid. (K-3115-1)

Schaeffer's group gave small clumps of rice cells a lethal dose of lysine and threonine (another amino acid) in a laboratory dish. Only a tiny percentage of cells survived the treatment. In those cells, the signal for lysine synthesis was changed, or mutated, allowing more lysine than normal to be made. The scientists grew the surviving cells into whole rice plants for their experiments.

"Test-tube inhibitor selections can help breeders sidestep the labor of sorting through dozens of incidental progeny of a cross that do not have a desired gene for a nutritional change. It can save many years of time and effort," says Schaeffer.

The scientists have begun work toward isolating the high-lysine gene biochemically in order to provide it to genetic engineers.—By **Stephen Berberich,** ARS.

Plant physiologist Gideon W. Schaeffer is in the USDA-ARS Plant Molecular Biology Laboratory, Beltsville, MD 20705 (301) 344-4342. ◆

Crops In Space!

COURTESY OF FINLEY HOLIDAY FILM CORP.

On some special day in the future, there could be research labs on the moon, orbiting stations, even a spacecraft on its 3-year journey to Mars. Freeze-dried food will no longer be a sufficient food supply for those long-term occupants of outer space.

Pioneers in space will eventually need to raise fresh fruits and vegetables to supplement their diet and possibly even grow wheat so space residents can bake their daily bread.

Several ARS researchers have been informally assisting NASA (National Aeronautics and Space Administration) to formulate the questions that must be answered before astronauts could ever reap a harvest in space.

Defining these questions has helped generate experiments that may provide new insights into basic plant physiology to benefit agriculture in its more traditional setting on Earth.

"Growing plants in any closed environment always raises questions of what conditions must be supplied," says Steven J. Britz, a plant physiologist in the Plant Photobiology Laboratory at the ARS Beltsville Agricultural Research Center in Beltsville, Maryland. "Just what is critical to producing a harvest when you have to meet every need from the outside?

You have to ask what kind of light, how much room for roots, what type of medium—soil or liquid culture, and how will plants react to the conditions?

Space can be viewed as the ultimate closed environment and raises a complex set of questions. In the closed environment of a space station or craft, the type and amount of compounds that plants release become important when they are not diluted in an atmosphere as large as the Earth's.

So do the compounds given off by the materials out of which the plants' habitat is built. What kind of trace metals are picked up and transported in recirculated water?

And not to mention the unknown effects of little or no gravity. All of the 2-day-old chicken embryos carried aboard the shuttle Discovery's flight last March failed to hatch. But embryos that were 16 days old at launch time developed normally.

"Growing plants in any closed environment always raises questions of what conditions must be supplied. Just what is critical to producing a harvest when you have to meet every need from the outside?"

Steven J. Britz, ARS plant physiologist, Beltsville, Maryland

Take light, as another example.

Most of the light for crops on a space station will have to be artificially generated. What happens to growth patterns when a space farmer is no longer tied to the rhythms or quality of sunlight on Earth?

"We already know that, in general, long nights result in relatively more shoot growth. During longer dark cycles, plants store more of the products of photosynthesis as starch," says Britz. "Maybe we can direct a plant to have more root growth or more shoot growth as we desire by having longer or shorter light-to-dark cycles than could occur in nature."

To develop specific information on the basic nature of plants' response to light, Britz has begun looking at the effects different levels of blue light have on soybean growth when the overall light intensity remains constant.

"We've seen that the blue component of light has a major effect on relative growth of roots and shoots," Britz says. "In a confined environment, you usually want to have as little of the resources go into the roots as possible and as much as possible to go into the shoots to maximize yields—unless, of course, you are growing a crop like carrots."

In his preliminary experiments, Britz sowed soybeans in chambers lit either with low-pressure sodium lamps—which emit no blue light, about comparable to the quality of light found in deep shade—or with fluorescent lights that simulate the natural daylight.

After 86 days, soybean plants grown under fluorescent light with blue in it partitioned 16 percent of their dry matter to root growth. Plants getting no blue light had only 8 percent of their dry matter in roots.

Response to the changes in the quality of light seems to take precedence over the general availability of nutrients or water, according to Britz.

Plants have special blue light photoreceptors, he explains. "These

In an effort to provide the essentials for long duration space missions, scientists at the Kennedy Space Center are developing a controlled ecological life support system, where plants recycle air, water, and waste to produce food. Their effort is currently centered in an old pressure chamber salvaged from the days of the Mercury 7 astronauts. (NASA 89-HC-1)

receptors sense the pigment in light somewhat like structures in the eye sense visual pigments. They differ from the energy-producing light receptors that guide photosynthesis."

"The quality of light obviously affects the partitioning of photosynthesis products," Britz points out. "Without blue light, much more product is retained in the leaves as starch."

Once it is learned how plants direct the partitioning of photosynthetic resources, it might be possible to manipulate plants to make them more efficient, whether they are grown on Earth or off, Britz says.

Though in space or other closed environment, light can be tailored to alter crops, it would be impractical on Earth to try to alter sunlight falling on a field, Britz says. "But since plants modify sunlight as a result of the shading created as plants grow taller, and shade has less blue in the light, we might be able to use indirect means to alter the light on crop plants. We could change planting or row widths or intercropping to create more or less shade as needed."

In the Climate Stress Laboratory, also at the Beltsville research center, plant physiologists Todd Peterson and Donald Krizek are studying what effect restricting root volume has on mineral uptake and on the plant hormones abscisic acid (ABA) and cytokinins. These hormones are important in regulating water loss and branching response in the plant.

In one project, Peterson and Krizek are setting up a flow-through recirculating hydroponic system to compare hormone levels and plant morphology when room for roots is reduced to less than 2 percent of the root volume for controls.

"Many basic questions need answering about just what happens to the form and structure of plants when you supply them with all the nutrients and light they can use but physically limit the volume the roots can take up," Peterson says.

In pilot studies, he found that up to the sixth or seventh week, tomatoes grown in liquid culture in large and small containers had similar root mass, but the roots of the restricted plants were interwoven and densely compact within their culture vessel. Shoots of the root-restricted plants were also somewhat smaller and had fewer leaves and flowers.

Now Peterson and Krizek are conducting studies to uncover what could be happening inside the plant to limit shoot and root growth under restricted root volume conditions.

"The root restriction could involve a mechanical stress caused by roots coming in contact with the walls of the container. The plant in turn may react by producing high levels of ethylene, which causes roots to become short, stubby, and highly branched," Peterson says.

Plant physiologist Todd Peterson is studying the effects of stress on tomatoes caused by restricting their root volume. These plants are growing in a flow-through hydroponic system. (K-3153-1)

Root growth of 6-day-old soybean plants is examined by plant physiologist Steve Britz for their response to different wavelengths of light. (K-3152-3)

"If growth hormones, such as ABA or cytokinin, are involved, it could be possible to alleviate the plant's restriction to increase branching and ultimately increase yield."

Because they are using a closed liquid culture system, the researchers will also be gathering data for a second experimental purpose. They'll collect the compounds that the roots release into the nutrient solution so they can study the compounds' importance as binders of metal ions.

In another experiment, Peterson and Krizek are studying the separate and combined effects of root restriction and water stress using a microporous tube system based on a NASA design for growing wheat.

NASA researchers at Kennedy Space Center have already shown that plants such as wheat can be grown and harvested from seed in liquid culture even when root volume is severely restricted.

Unlike hydroponic systems on Earth, for space farming, plants will be unable to absorb water or nutrients in the form of water droplets. In weightlessness or very small simulated gravity from centrifugal force, the liquid will have to be absorbed as a thin film to keep it from floating away.

The system Peterson and Krizek are adapting uses two plastic pipes, fitted one inside the other. The inner tube is wettable and porous. It serves as the source from which the roots draw nutrients and as a support matrix for the roots.

By increasing the suction in the pipes against which the plant must extract moisture or nutrients through a membrane, the researchers will be able to subject plants to a measurable

range of water stress while still delivering ample nutrients.

"Eventually this work may give us a handle on some basic physiological responses to drought and thus further develop characteristics for breeding resistant plants," Peterson says.

Since pioneering studies on controlled-environment seedlings were first published by Krizek and his associates at Beltsville in 1968, there has been keen interest by industry, academia, and governments in the concept.

Considerable interest was shown in a recent visit by delegates from the Chinese Agricultural Ministry. In their country, there is a growing industry raising hydroponic vegetables for the hotel industry.

"They are very interested in raising maximum yields in very confined spaces," Peterson says.

In addition to Krizek's work supervising the Climate Stress Laboratory, he is also chairman of the American Institute of Biological Sciences Biomass Production Panel at Kennedy Space Center as well as a member of the AIBS Plant Physiology Advisory Panel on Controlled Ecological Life Support System Committee.

The main job of these advisory groups is to establish guidelines for standardizing controlled environment research in NASA, USDA, and other organizations. Krizek has been advising NASA's crops-in-space efforts since the mid-1970's.

"When people think of controlled environment research, they usually think of growing crops in a place like a spacecraft. But using controlled environments lets us find the optimum condition for a particular plant, which may not be the same as its natural environment," Krizek says.

We are beginning to appreciate that Earth is just as much a closed environment, and we need to learn how plants can adjust to it.

For example, the Monterey pine is of little economic value in its native California, but it turned out to be a great timber tree in New Zealand where the temperature and light are perfect for it, according to Krizek.

"Studying plants in controlled environments allows us to determine which factors affect growth, yield, even disease and insect resistance," he added. Controlled environment studies led to the discovery that it was low night temperatures that benefit the Monterey pine.

With mounting concerns over possible global warming trends, controlled environment facilities will take on increasing importance as a tool for studying the mechanisms plants use to adapt to environmental stresses," Krizek says. "They will also gain increasing acceptance as a viable means of commercially growing high-value crops under scheduled production management in an environment free of insects and pollutants.—By **Kim Kaplan,** ARS.

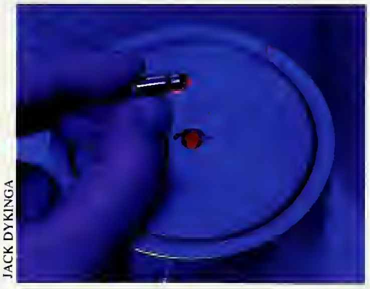
Steven J. Britz is in the USDA-ARS Plant Photobiology Laboratory, BARC-West, Beltsville, MD 20705 (301) 344-3607. Donald T. Krizek and Todd A. Peterson are in the USDA-ARS Climate Stress Laboratory, BARC-West, Beltsville, MD 20705 (301) 344-4526. ◆

Tomatoes growing in a plant culture system designed for NASA are measured by ARS plant physiologist Todd Peterson at the Beltsville (Maryland) Research Center. The system uses an inner porous tube and an exterior PVC tube—one inside the other—to support plants and provide nutrients. (K-3151-13)

Plant physiologist Steven Britz prepares to measure photosynthetic CO_2 uptakes in the leaves of young sorghum seedlings that have been subjected to various "night lengths." (K-3154-1)

Blast Those Genes!

JACK DYKINGA



JACK DYKINGA

JACK DYKINGA

From left: microbiologist Theodore Klein uses a pipette to place the gene-and-tungsten mixture that will be blasted into plant cells within the gene gun (background). The .22 caliber cartridges are of the type used in standard construction nail guns. Geneticist Michael Fromm examines a projected slide that shows tissue from a kernel of maize after bombardment by gene gun microprojectiles. Red spots represent cells that have taken up the new gene. (K-3090-12) (K-3090-4) (K-3091-2)

Genes carried on tiny pellets that race into plants at nearly 1,000 miles an hour may carry useful new traits to crops of the future. The pellets are metal particles so small that they resemble a fine powder. They're propelled by a gene gun or "bioblaster," biotechnology's new assault weapon on recalcitrant plants that stubbornly refuse to accept new genes.

The resisting plants unfortunately include several of our main food crops—corn, wheat, rice, and other plants that belong to a class called monocots. They are typically immune to tactics that have worked successfully with tomato, tobacco, and other species in the class known as dicots.

The amenable dicots, for example, are readily infected in nature by a bacterium *(Agrobacterium tumefaciens)*. Scientists can manipulate the bacterium so that it carries new genes into the dicots. But the bacterium isn't as helpful with cereal crops because it's generally unable to infect them.

These typically difficult-to-engineer grains are the target of research geneticist Michael E. Fromm and research microbiologist Theodore M. Klein of the Agricultural Research Service/University of California Plant Gene Expression Center in Albany, California.

The researchers estimate that they're only a year or two away from getting corn to accept new genes using the gene gun method. They're using the gun developed in 1983 by Cornell University researchers John C. Sanford, Edward D. Wolf, Nelson K. Allen, and Klein, who was then at Cornell.

The technique Fromm and Klein use is basically the same as that which researchers in some 20 labs throughout the United States, Europe, and Canada are following to genetically engineer target organisms with the bioblaster.

Klein and Fromm start by mixing sample genes with millions of tungsten particles, coating the particles with the genetic material (DNA). That mixture—a dark-grey soup—goes inside a small white plastic cylinder, which in turn is positioned in the path of the gene gun's .22-caliber blank cartridge.

With the push of a button, the gun's electrical firing pin hits the cartridge, setting off the gunpowder. The force of the exploding gunpowder sends the plastic cylinder down the gene gun's barrel and into a steel plate. The plate stops the cylinder, but its contents—the genes and tungsten mixture—escape, shooting out through a small hole in the plate and crashing into the leaf, stems, embryos, or cells waiting in the petri dish below.

A vacuum pump (connected by hose to the gun) sucks air out of the chamber that the particles move through so that they can travel with little resistance, gaining the momentum they must have in order to punch through the tough cell wall and the cell's inner lining (membrane).

The particles are so small that they need all the velocity they can get.

Often they are 10 or more times smaller than the cells they'll pierce.

The process needs fine-tuning, says Klein. For example, although many thousands of cells are penetrated simultaneously—an important time-saver—others may be untouched. And not every cell that is bombarded will accept the gene as part of its own genetic material.

Nevertheless, Fromm predicts that particle bombardment will become "one of the most useful techniques for genetic engineering of plants."

One reason: the technology is unusually versatile. Cornell's Sanford says it has been used successfully to deliver new genes into organisms ranging from yeast to algae to "higher plants" as well as to animal and human cells.

And that list now includes tobacco, a plant often used in laboratory tests. In 1988, Klein and Fromm were the first to use the 45-pound bioblaster to genetically engineer that crop, using sample or "marker" genes. Success in such experiments requires that the healthy, fertile plants growing from bits of bombarded tissue have the new gene or genes actively working inside.

Another good reason for keeping the apparatus in the molecular biologist's arsenal is that mutations, unwanted in some research yet almost unavoidable with many genetic engineering approaches, are infrequent with the bioblaster.

Further, the process uses intact cells. With monocots, it's easier to produce plants from these cells than from protoplasts (cells that have had their outer wall stripped away). Yet some genetic engineering techniques rely on protoplasts.

Electroporation is one example: that process uses an electric current to briefly create a tiny opening in the protoplast's membrane so that genes can enter.

And the microprojectile technique requires only very small amounts of genetic material—a real advantage for most scientists.

Sanford says the particle gun idea came about after his unsuccessful attempts to use lasers to create a cell wall opening genes could slip through. "People kept telling me I should go see Ed Wolf," says Sanford of his co-inventor. A professor of electrical engineering at Cornell, Wolf is best known for his work with particle beams—the kind used for such precision tasks as etching miniature circuits for computers.

It was good advice. Less than a year after Sanford and Wolf first began tossing ideas back and forth, they filed a patent application for the particle bombardment process and gene gun device. They describe the technology as a linking of biology and ballistics, or "biolistics."

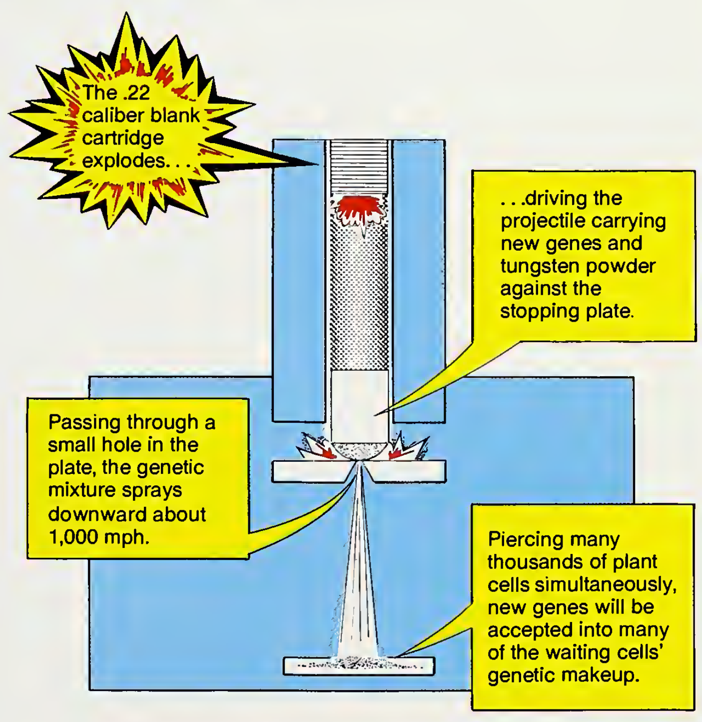
Scientists at Agracetus, an agricultural biotechnology company in Madison, Wisconsin, are using a similar approach. The process has "worked with every plant we've tried," says an enthusiastic Winston J. Brill, vice-president for research and development.

Agracetus scientists scored what was apparently a genetic engineering "first" in 1988 when they used the particle bombardment process to transfer genes into soybean plants.

These successes and others have encouraged biotechnologists who are now working to exploit the microprojectile technology. In a very short time biolistics has become one of genetic engineering's most powerful weapons.—By **Marcia Wood,** ARS.

Theodore M. Klein and Michael E. Fromm are with the USDA-ARS/UC Berkeley Plant Gene Expression Center, 800 Buchanan Street, Albany, CA 94710 (415) 559-5908. ◆

Gene Transfers With a Bioblaster



Ground-Nesting Bee Best for Blueberries

What helps produce more and bigger rabbiteye blueberries that ripen earlier? A blueberry bee, of course.

But who's ever heard of a blueberry bee? ARS entomologist Jerry A. Payne, for one.

Payne, in a 3-year cooperative study with Auburn University entomologist James H. Cane, came up with some fascinating facts about blueberry pollination.

They discovered that a ground-nesting bee—which they named the southeastern blueberry bee—is the principal pollinator of the rabbiteye blueberry. Pollination is the result of insects sonicating or buzzing flowers—scattering pollen particles by vibrations created from rapidly vibrating flight muscles.

The motion, says Payne, is like that of a tuning fork; it can't be seen with the naked eye. Bees help transfer the pollen from the anthers of one flower to the stigma, the pollen-receiving female part, of a different flower.

The rabbiteye, which is native to the South, grows up to 12 feet tall, the largest of the three main blueberry types in the United States.

In field tests, rabbiteye plants visited by this bee (*Habropoda laboriosa)* produced bigger berries and more of them in less time than other plants that had been caged to exclude bees.

"Inadequate commercial crops of rabbiteye blueberries have often been the result of poor cross pollination," says Payne, who is with the Southeastern Fruit and Tree Nut Research Laboratory in Byron, Georgia.

Rabbiteye blueberry flowers are nearly sterile, so they must be pollinated to bear fruit. Payne says the blueberry bee buzzes the blueberry flower, releasing a spray of pollen. This pollen collects on the bee's hairy mouth and face. As the bee moves on and probes other flowers, pollination is accomplished.

"Cross pollination," Payne says, "means more, better quality berries earlier. You often pick rabbiteye blueberries four different times during a season. With cross pollination, more of the berries can be harvested at the first picking, between 4 to 7 days early."

The rabbiteye flower carefully guards its pollen and nectar. Nectar collects at the deep base of the petals that are two- to four-tenths of an inch long. There's a tiny opening (about one-tenth of an inch wide) at the end of the flower. This narrow passageway limits a bee's access to the nectar and pollen. It's too small to accommodate the bee's body and too deep for some bees' tongues.

Because access is denied them through the natural openings, carpenter and honey bees puncture tiny holes in the base of the rabbiteye flower (which hangs upside down, like an inverted vase) to get nectar. Commonly called robber holes, these openings do not yield pollen.

"A pollinating bee puts its tongue into a flower and then buzzes it to loosen a cloud of pollen," Payne continues. This, he says, is easy for the blueberry bee because it has a longer tongue than a honey bee or most other bees.

Auburn University entomologist Cane says it's practically impossible for a honey bee to adequately pollinate the rabbiteye blueberry, despite the custom of locating hives near berry fields.

"When you see a honey bee in a berry patch, it's probably stealing nectar through robber holes," Cane says.

Larger than a honey bee but smaller than a bumble bee, the female *H. laboriosa* has a black face minus the cream-colored dot that distinguishes the male from the female. Only the female gathers pollen.

"It's a busy little bee," Payne says, "working from early morning to

KEN TOUCHTON

Entomologist Jerry Payne listens with a bionic ear for blueberry bee's sonication. (K-3160-1)

KEN TOUCHTON

Female southeastern blueberry bee forages for pollen and nectar at rabbiteye blueberry flower. (K-3161-1)

sundown. Each minute, it gathers pollen from about 15 to 25 blueberry blooms."

Although partial to the rabbiteye, this special bee also likes our wild blueberries and redbud trees.

Prevalent in the southeastern United States where rabbiteye blueberries grow on about 5,000 acres, *H. laboriosa* is also found from New Jersey west to Illinois and as far south as Florida. It is active from February through April.

This bee can be very important to small farmers in the South, where the rabbiteye blueberry is increasingly being grown as an alternative crop.

"We don't know much about this solitary bee's subterranean nesting habits yet," says Payne. "Therefore, we don't have any way to reintroduce it if nests are destroyed. Our advice to growers is: Don't use insecticides when the blueberry is in bloom."—By **Doris Sanchez,** ARS.

Jerry A. Payne is at the USDA-ARS Southeastern Fruit and Tree Nut Research Laboratory, P.O. Box 87, Byron, GA 31008 (912) 956-5656. ◆

Kenaf Tops Equal High-Quality Hay

The same tropical plant that may provide backing for your dining room rug and newsprint for your morning paper could also help grow your dinner steak, scientists say.

The plant is kenaf, or *Hibiscus cannabinus*. It looks like bamboo and is considered an important contender against jute from Southeast Asia as a source of rope and fiber.

It's also being seriously considered as a source of roughage and protein for cattle and sheep. The upper 2 to 3 feet of the plant, normally left to rot in the fields when kenaf is harvested for fiber, can be ground into a feed ingredient with digestibility equal to that of high-quality hay.

Kenaf also has a crude protein content ranging from 15 to 22 percent depending on the part of the plant used.

"We're going to try feeding it to animals as a protein supplement," says William A. Phillips, an animal scientist at ARS' Forage and Livestock Research unit at El Reno, Oklahoma. "We expect a digestibility of 65 to 70 percent, which is very good, about the same as alfalfa." The next question is, will animals eat the stuff?

"We planted about 2 acres of kenaf last May," Phillips says. "We harvested some at 80 days of growth and fed the whole plant to six lambs. They ate the leaves and leaf stems but didn't want to eat the stalks.

"However, if you increased the plant density per acre, the stalks would be smaller. The ideal plant population would be 80,000 to 100,000 plants per acre, and we only had about 30,000.

Even with only 30,000 plants per acre, Phillips and his fellow researchers collected about 500 pounds of dry matter per acre of kenaf.

"If you're raising kenaf for some other purpose, this would give you another crop to sell," he notes. "The tops could be worth $20 to $30, based on the value of comparable alfalfa hay."

If the whole plant is used as forage, the kenaf producer may be able to get two crops per growing season, Phillips says.

"When you harvest the first time, if you leave 4 or 5 inches of stubble, depending on available moisture you can get a second crop," he says. "Where you cut the first stalk, it usually comes back as more than one plant, and you can harvest again in 60 to 70 days."

"Depending on market prices, it may be more advantageous to harvest kenaf as feed. If we have a kenaf industry develop for fiber, the tops could be harvested for a whole second crop."—By **Sandy Miller Hays**, ARS

William A. Phillips is in USDA-ARS Forage and Livestock Research, P.O. Box 1199, El Reno, OK 73036 (405) 262-5291. ◆

(Photo by David Nance, courtesy of USDA/CSRS)

A prototype harvester cuts mature kenaf in the lower Rio Grande Valley of Texas. It was developed cooperatively by USDA and private industry. (Photo by David Nance, courtesy of USDA/CSRS)

From the Flower Garden, Natural Insect Resistance

The petunia—a distant relative of the familiar red tomato—contains natural insecticides that apparently help the plant fend off the destructive tomato fruitworm *(Heliothis zea)*.

ARS chemists have discovered natural chemicals in petunia leaves and stems that confer this resistance. When fed to fruitworms in lab tests, the chemicals—named petuniolides and petuniasterones—killed young tomato fruitworm larvae and stunted the growth of older worms.

Studies of two other tomato relatives, cape gooseberry and tomatillo, suggest chemicals in these plants may also defend them from the fruitworm.

Tools of modern biotechnology, such as protoplast fusion and microinjection, may make it possible for scientists to transfer natural resistance into tomatoes from its relatives. Similarly, crops such as potato, corn, cotton and soybean that the tomato fruitworm attacks might be protected.—By **Marcia Wood,** ARS.

Carl A. Elliger and Anthony C. Waiss, Jr., are in the USDA-ARS Plant Protection Unit, Western Regional Research Center, Albany, CA. (415) 559-5820. ◆

Patents

Zinc Helps Keep Fruits Fresh

An edible zinc chloride solution safely delays unsightly browning of fresh apples, pears, or peaches that are sliced into halves, sections, chunks or similar pieces, and then bagged and refrigerated.

Browning is caused by a polyphenol oxidase enzyme that is released from cells when they are sliced or chopped, says research chemist Harold R. Bolin of ARS' Western Regional Research Center, Albany, California.

The zinc chloride bath works better—by itself or in combination with calcium—than calcium compounds alone to keep the light color and firm texture of fresh fruit, according to the scientist.

Just how effective the dip is varies with the type of fruit treated. Bolin's experiments show that the treatment may fend off browning of presliced fruit that is refrigerated in bags from several days up to 10 weeks or more. Although fruit he has treated hasn't been sampled by a formal panel of taste testers, Bolin says those who have nibbled at experimental samples report that flavor and aroma appear to hold up well.

The treatment is easy to apply: Fruit pieces are dunked in water that contains a very small amount of zinc chloride or zinc chloride plus some form of calcium such as calcium chloride. In some cases, priming fruit pieces with ascorbic acid (vitamin C) or citric acid makes the bath even more effective.

Bolin says Americans want fresh or freshlike fruits but they also want convenience. The zinc process meets both needs: It helps retain more of the freshlike quality of fruit than may be possible with freezing, canning, or drying, yet helps food processors improve upon nature's packaging.—By **Marcia Wood**, ARS.

For technical information about this patent, contact Harold R. Bolin, USDA-ARS Process Chemistry and Engineering, Western Regional Research Center, 800 Buchanan St., Albany, CA 94710 (45) 559-5863. Patent Application Serial No. 07/270,979, "Zinc Treatment for Stabilizing Lightly Processed Fresh Fruits." ◆

Less Pickleworm Pesticide

A box trap and a pheromone synthesized by ARS scientists may help farmers cut their pesticide war on pickleworms almost in half.

A major insect problem, pickleworms follow spring north each year to lay eggs in the 50,000 acres of cucumbers in North and South Carolina. As summer progresses, the insect becomes a problem in states farther north.

The adult pickleworm moths lay eggs in the fields. Larvae hatch and eat their way into young cucumbers.

Growers start spraying their fields with potent pesticides almost every week for the moths' 6- to 7-week season as soon as the nighttime temperature reaches 60°F—the temperature the moths follow north. Whether they actually see any pickleworms or not makes no difference. Once the temperature reaches the critical point, the growers spray.

Why the worm witch hunt? It's because pickle packers will refuse to accept a truckload of cucumbers if they notice even one with a pickleworm hole. (Understandably enough—imagine biting into a pickle and finding...)

But Agricultural Research Service entomologist Kent D. Elsey of the U.S. Vegetable Laboratory in Charleston, South Carolina, plans to end the blitzkrieg approach to crop protection. Elsey devised a warning system so that farmers need apply pesticides only when there are actually pickleworms in the fields.

A pheromone—a naturally produced scent that attracts—is placed inside 3-foot-square box traps out in the fields. The male moths following the pheromone scent fly into the boxes and become trapped inside.

"Once the adult pickleworm moths start appearing in the traps, it is time to begin spraying" Elsey says.

The pheromone, which moths produce naturally, was synthesized by Jerome A. Klun, of the Chemical Ecology Laboratory at the Beltsville Agricultural Research Center in Beltsville, Maryland.


FRED WITTE

Pickleworm moth (K-1550-6)

"It takes very little of the pheromone to bait each trap—just a tiny amount on a bit of rubber about the size of a pencil eraser, and it lasts about a week," Elsey says.

In recent trials, using the traps to monitor for the presence of moths, Elsey was able to control the pickleworm with about half the number of sprayings.

"Some years pickleworms don't appear at all, and in those years growers could avoid any spraying for them if a monitoring system like this were in place," Elsey says.

Some day Elsey envisions a line of traps that extension agents or others could check and then send out appropriate warnings or all clears—kind of an early warning line against pickleworms.—By **Kim Kaplan**, ARS.

Kent D. Elsey is with the U.S. Vegetable Laboratory, 2875 Savannah Highway, Charleston, SC 29407 (803) 556-0840. ◆

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